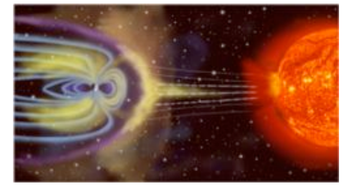
Auroral Ionosphere as a Source of Magnetospheric Plasma



T. E. Moore(1), M. C. Fok(1), J. L. Horwitz(2), R. J. Strangeway(3), and Y. Zheng(4)

(1) NASA's Goddard SFC, Greenbelt, MD USA (thomas.e.moore@nasa.gov)

(2) University of Texas at Arlington, USA

(3) University of California, Los Angeles, USA

(4) Applied Physics Laboratory, Laurel MD USA

Abstract/Outline:

Observed fact: heavy ion plasma expands upward into magnetosphere with solar wind energy inputs, inflating magnetosphere

"Auroral Wind", by analogy with Solar and Polar Winds

Driven by dissipation of solar wind energy into topside ionosphere

Both kinetic heating via precipitation and heating by Poynting EM flux

Lyon Fedder Mobarry MHD global circulation models ionospheric inputs

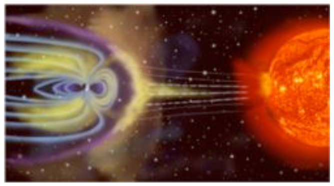
Ionospheric global outflows assessed, compared with statistical data sets

Conclusion: simulated substorm events also produce substantial O^+ global outflows, match or exceed statistical outflows

Reprint: http://temoore.gsfc.nasa.gov/public/

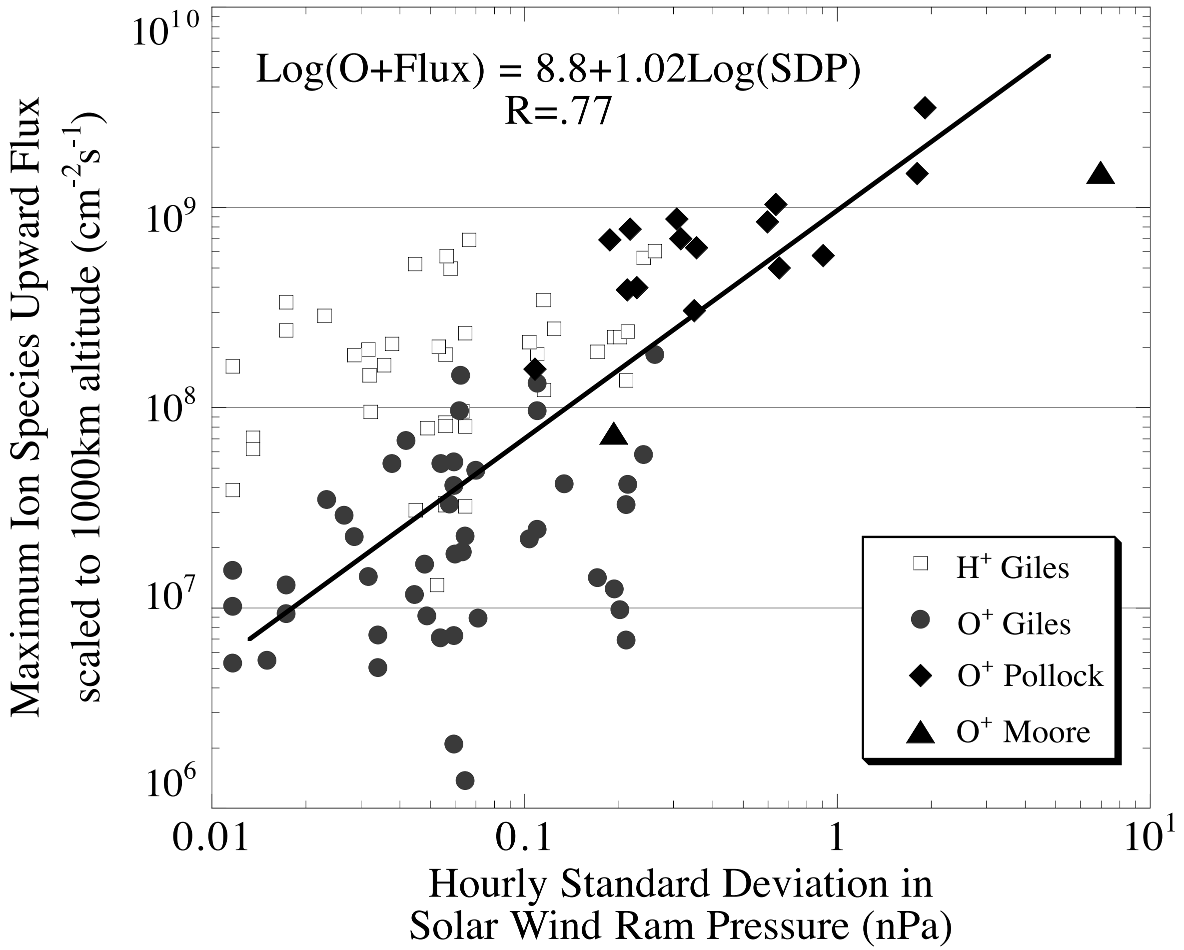
Movies: http://hpb.gsfc.nasa.gov/public/traj/

O^+ Outflow Grows with ∇Pd
(H^+ doesn't)

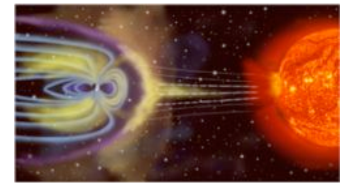


- Cusp dayside auroral region outflows:
- Strong correl. with Pd variability
- Weak correl. with IMF Bz
- Largest fluxes seen in superstorms, up to 2 x 10^{10} $cm^{-2}s^{-1}$

Moore et al., 1999GRL, 2001RSS

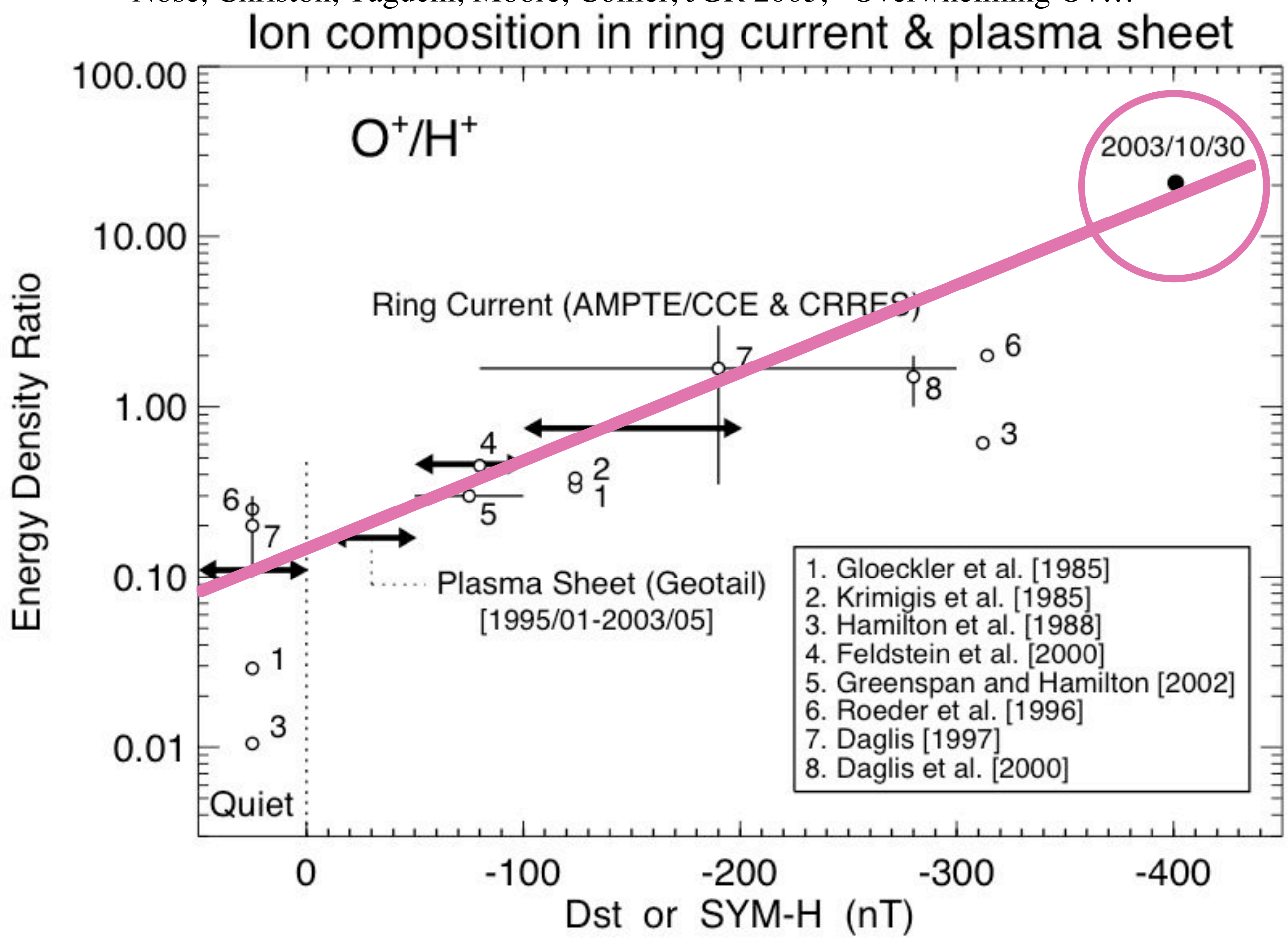


O^+ Grows Exponentially with Dst
(H^+ doesn't)

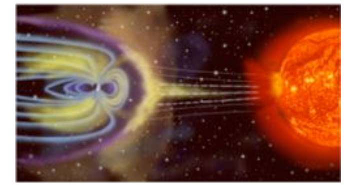


- H^+ relatively indep. of Dst
- Inner Plasma Sheet and Ring Current
- Numerous consistent results
- O^+ exceeds H+ for Dst < -150
- Overwhelming in superstorms

Nosé, Christon, Taguchi, Moore, Collier, JGR 2005, "Overwhelming O+…



Local Auroral Wind OutFlow Conditions

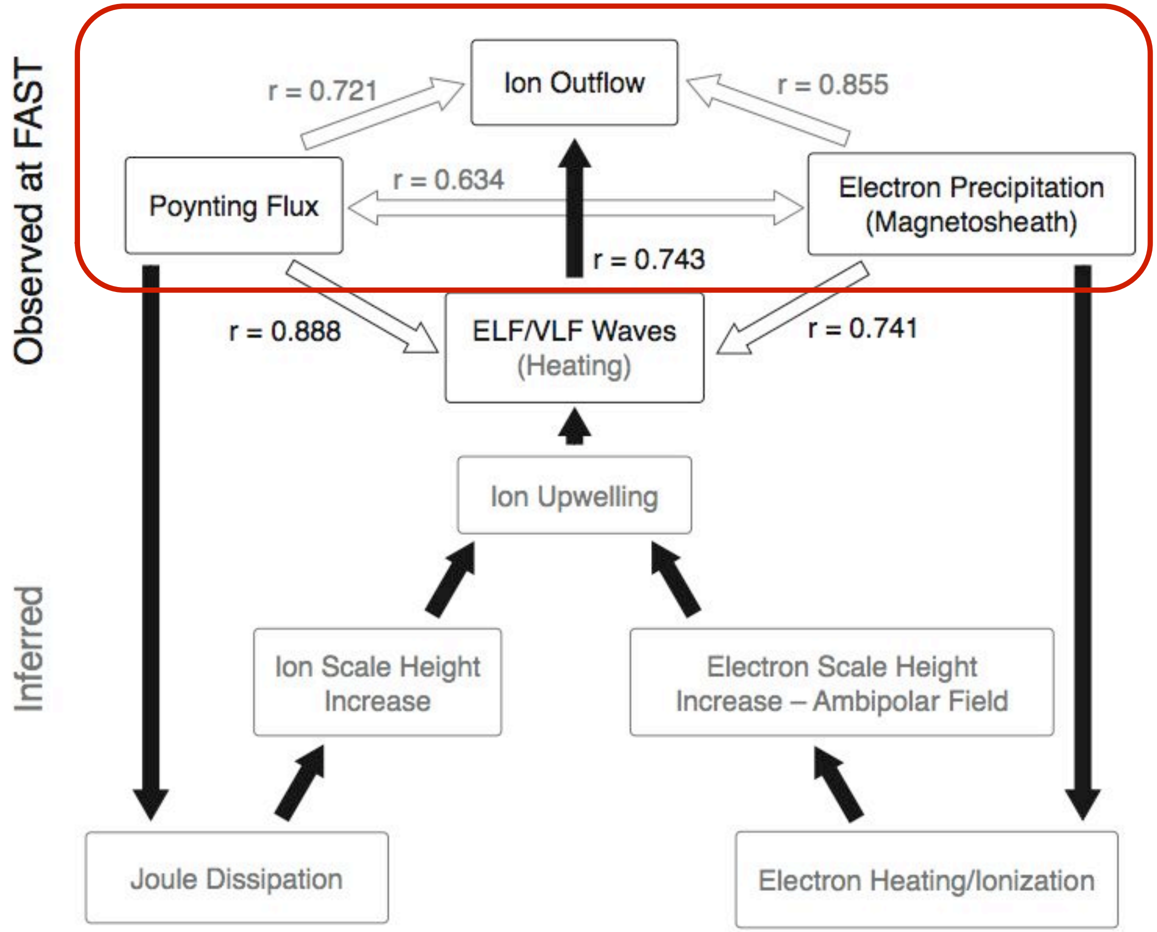


Dst, Kp, AE internal, global

IMF, Pd external, but don't specify full spatio-temporal dynamics

Factors:

1. Ion heating:
   a. Poynting Flux
   b. Thermal ion heating
2. Electron heating:
   a. Ne precip. (>50 eV)
   b. Thermal electron heating
3. Both needed for outflow
4. Ion heating proxy for ELF
5. PA diff'n for precipitation
6. Limiting O^+ flux exists



Strangeway [2005 JGR]; Zheng [2005 JGR]

Causal Possibly Causal Correlated

Specifying O^+ Outflows

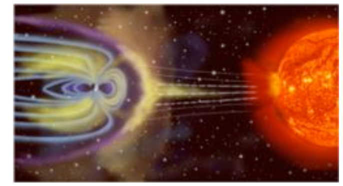
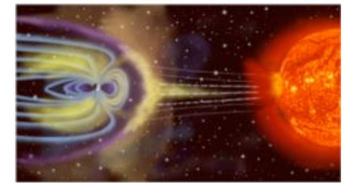
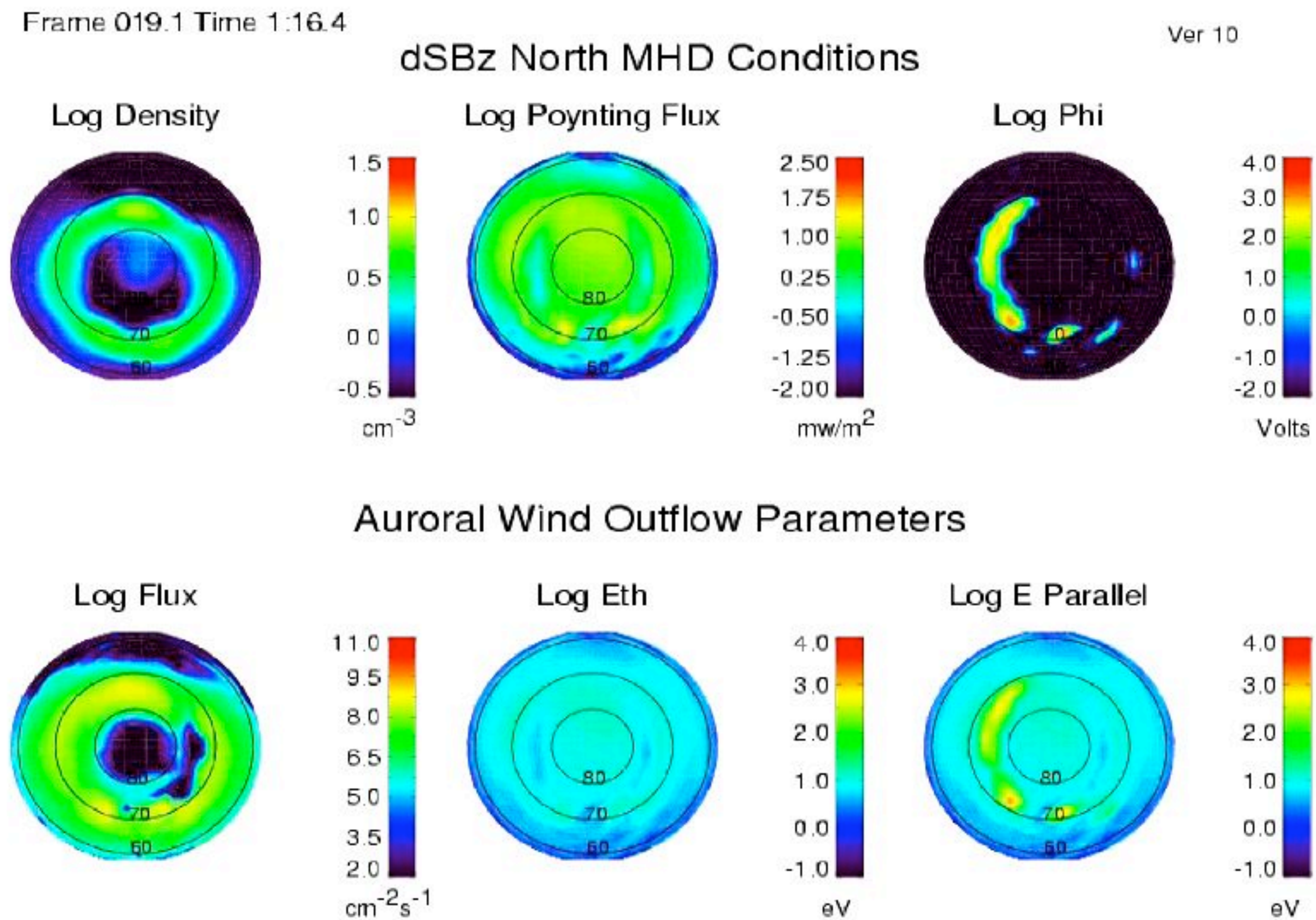


Table 1. Local empirical scalings used to initialize ionospheric particles

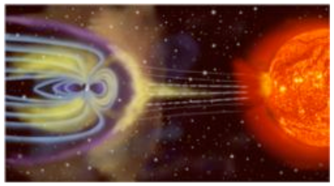
Parameter	Scaling	Notes
Auroral wind	NVprecip = 2.8e9 ×$(Nei)^{2.2}$ [$cm^{-2}s^{-1}$]	Nei is LFM density in cm^{-3}
O+ flux	NVpoynt = 5.6e7 ×$(0.245*S_{120})^{1.26}$ [$cm^{-2}s^{-1}$]	above instrumental 50 eV
	NV = √(NVprecip × NV poynt)	in loss cone with filling per
	Strangeway et al. [2005 JGR]	Chen and Schulz [2001 JGR]
	Zheng [2005 JGR]	S_{120} is LFM Poynting flux in mW/m^2
	G. mean makes both necessary for outflow	at 120 km altitude; 0.245 maps from
	All fluxes mapped to 1000 km altitude	120 to 4000 km alt.
Auroral wind	0.1 + 9.2*$(0.24*S_{120})$^0.35 [eV]	Strangeway [private communication]
O+ temperature		
Parallel energy	$E_{//}$ [eV] = E_{th} + ePhi[V] where	Lyons [1981 Geo.Mono. 25]
	Phi[V] =1500[$V/\mu Am^{-2}$] *$(J_{//} - 0.33)^2$	Threshold current 0.33 $\mu A/m^2$
	[$\mu A\ m^{-2}$]	Also applied to polar wind, below
Polar Wind	0 < SZA < 90: $F_{1000} = 2x10^8\ cm^{-2}s^{-1}$	Su et al., [1998 JGR] solar zenith angle
H+ flux	90 < SZA < 110:	(SZA) dependence
	NV_{1000} = 2 x 10^(8-(SZA-90)/20*2.5)	All fluxes at 1000 km altitude
	110< SZA < 180: $F_{1000} = 2 \times 10^{5.5}$	

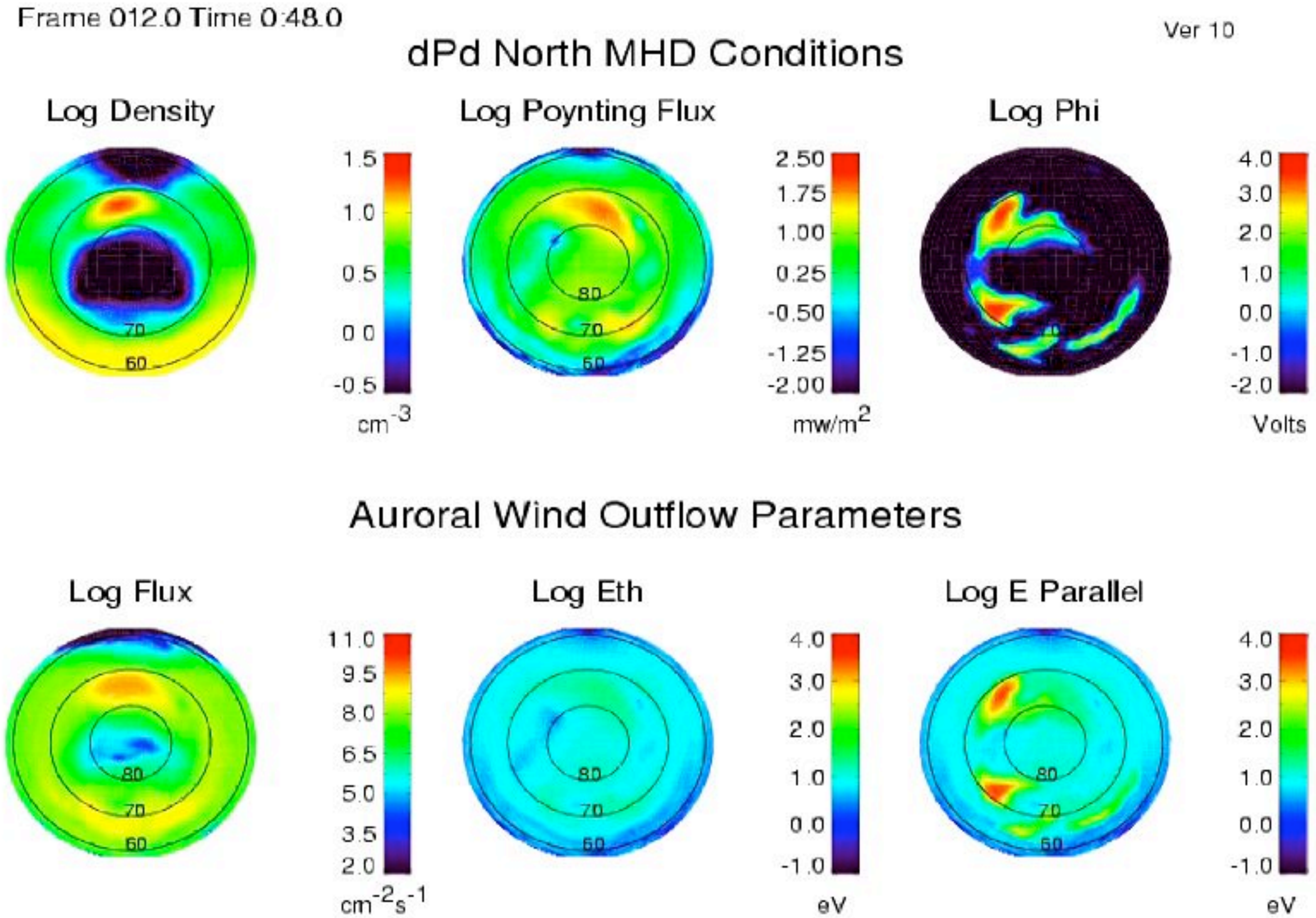
Boundary Conditions: SBz



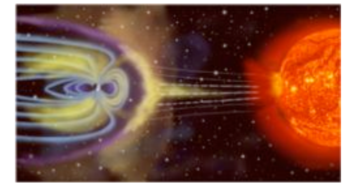


Boundary Conditions: ∇Pd





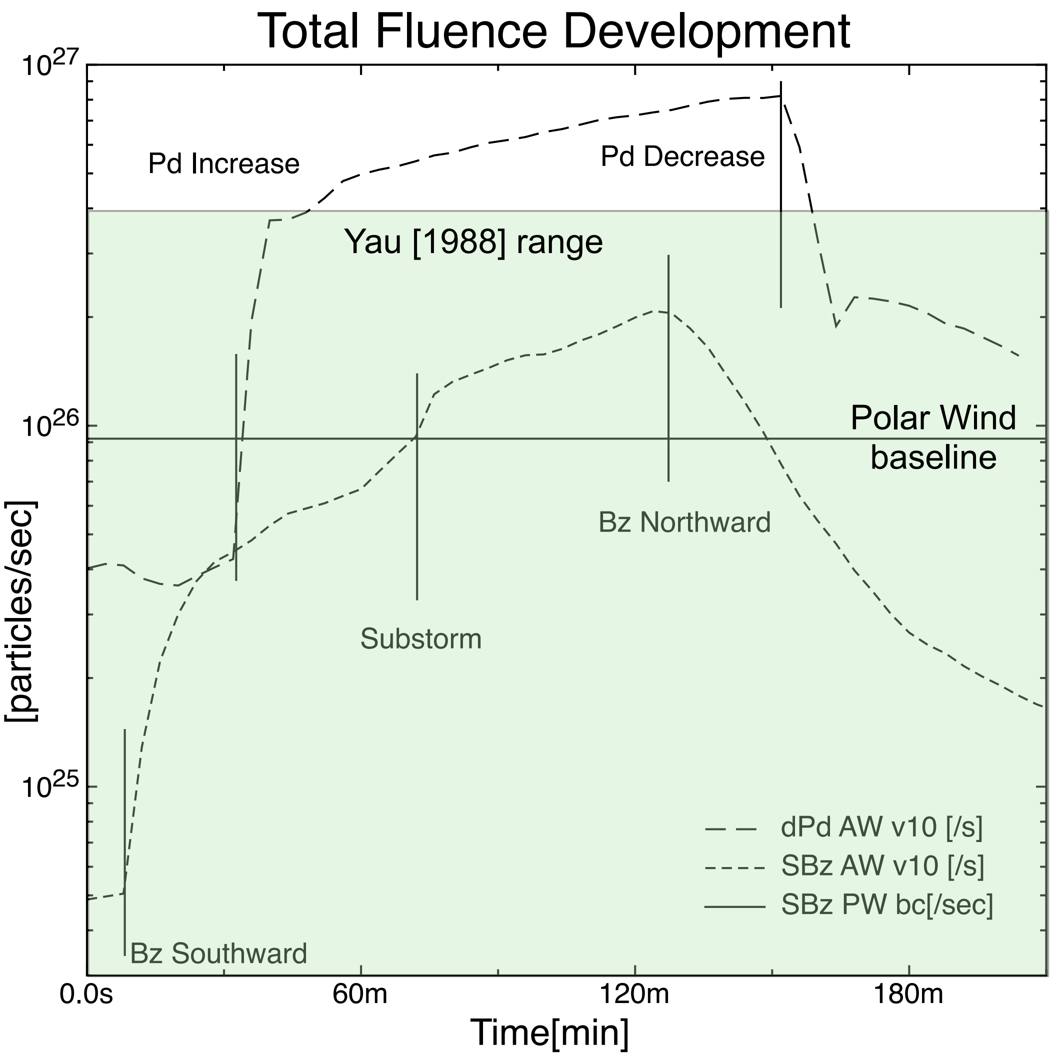
Global Auroral Wind Outflow Fluence



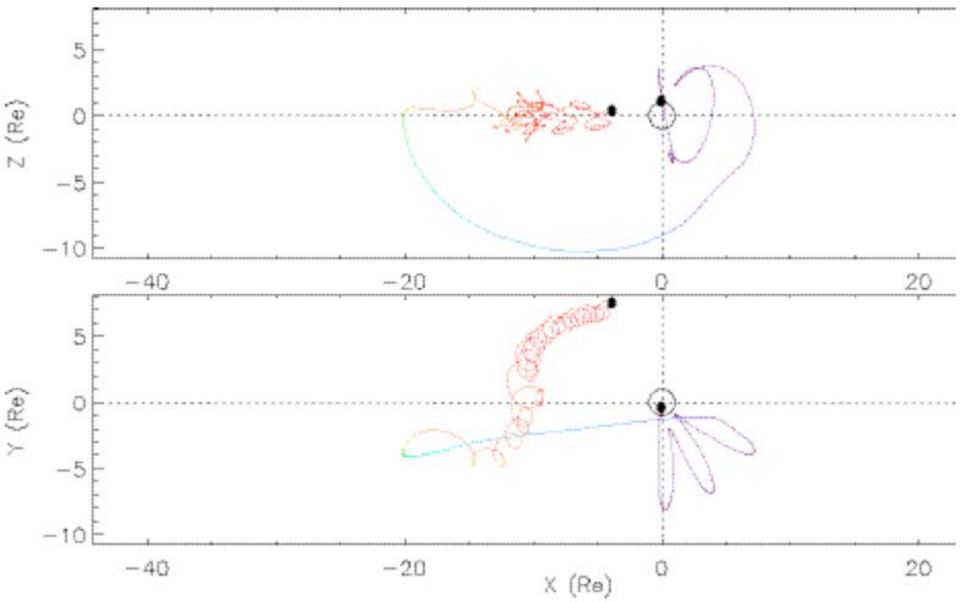
- Top Trace:
  fluence during a period of enhanced dynamic pressure (4.5 nPa) with steady EBy

- Bottom Trace:
  fluence during a substorm sequence from NBz to SBz to NBz at 0.8 nPa

- Note Yau 1988 range

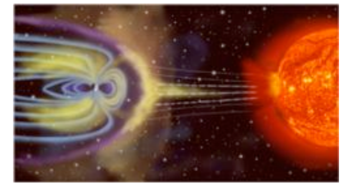


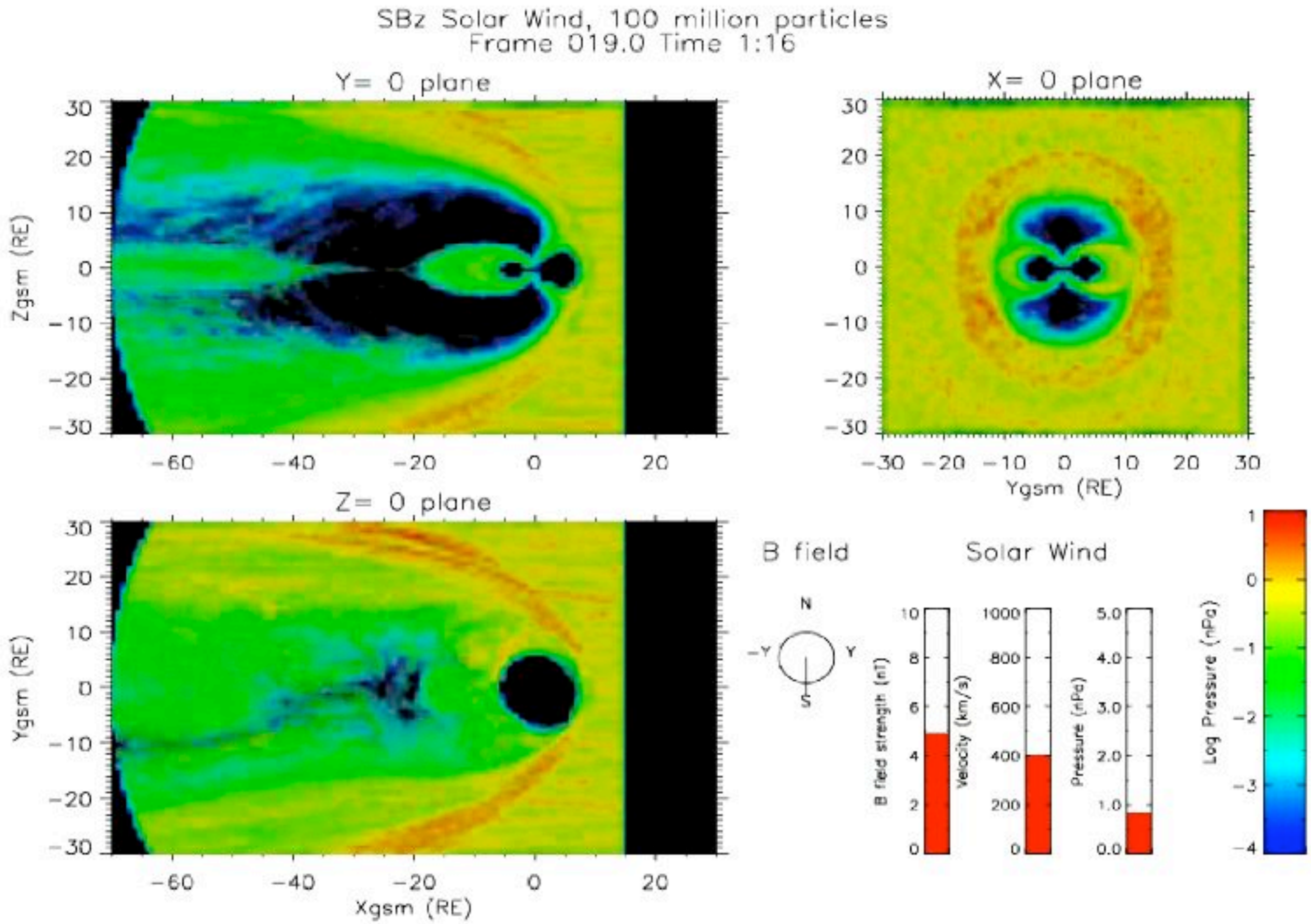
Test Particles in LFM



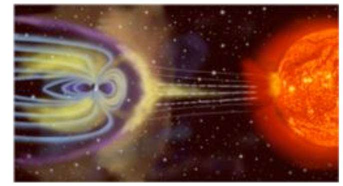
- Strengths:
  - Pathways can be traced
  - Drifts and non-adiabatic beha
  - Dynamic importance of ionos
- Weaknesses:
  - Problematic to do plasmaspheric ions
  - Inner magnetospheric convection strength lacking
  - Not self consistent since no O^+ load on system
- Opportunities:
  - Embed inner magnetosphere model, e.g. CRCM
  - Integrate dynamic auroral wind into global simulation
- Threats:
  - Improved understanding and predictions

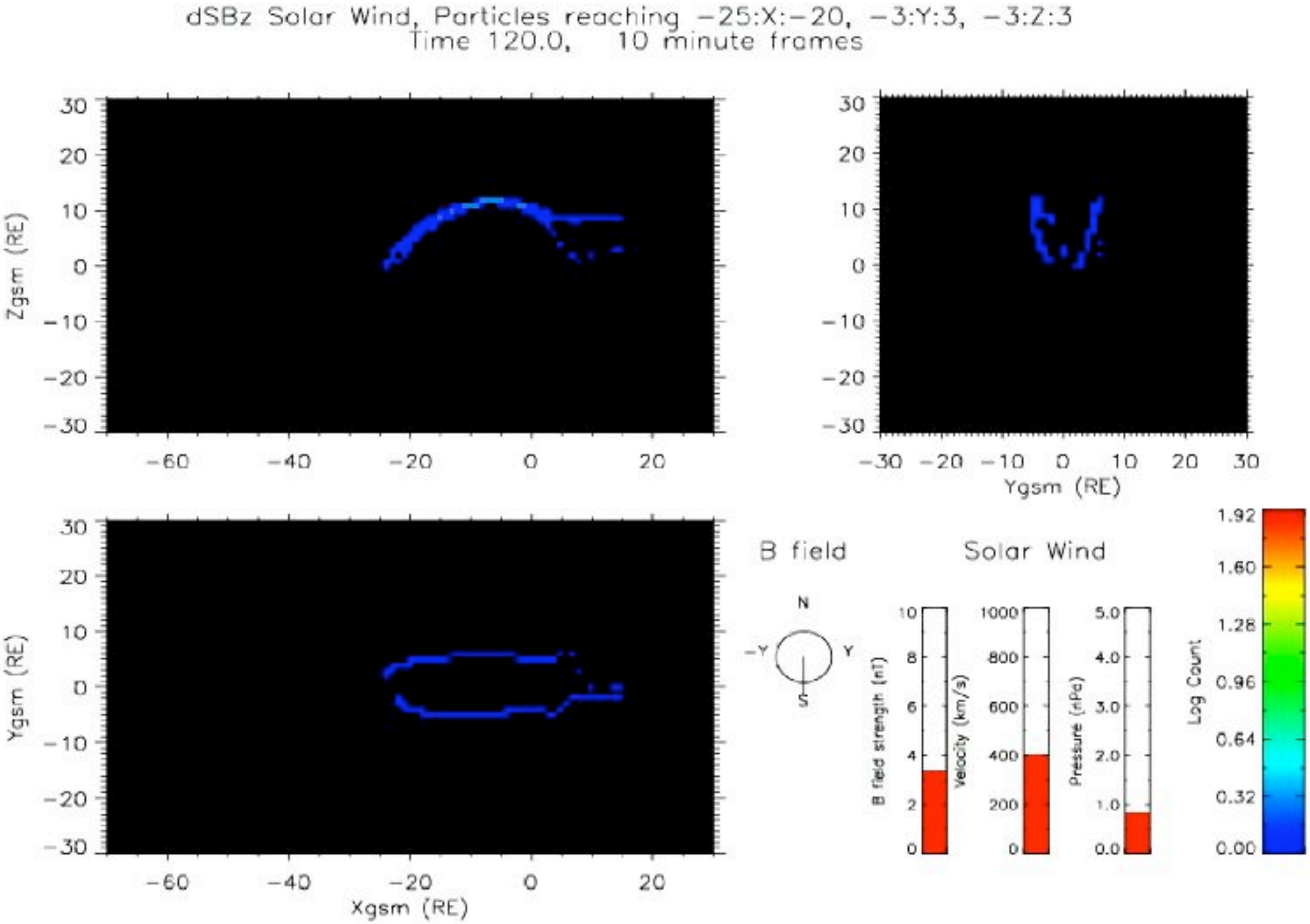
Solar Wind for N/SBz



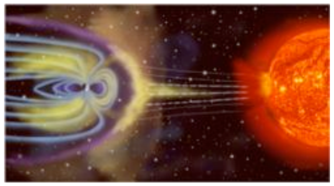


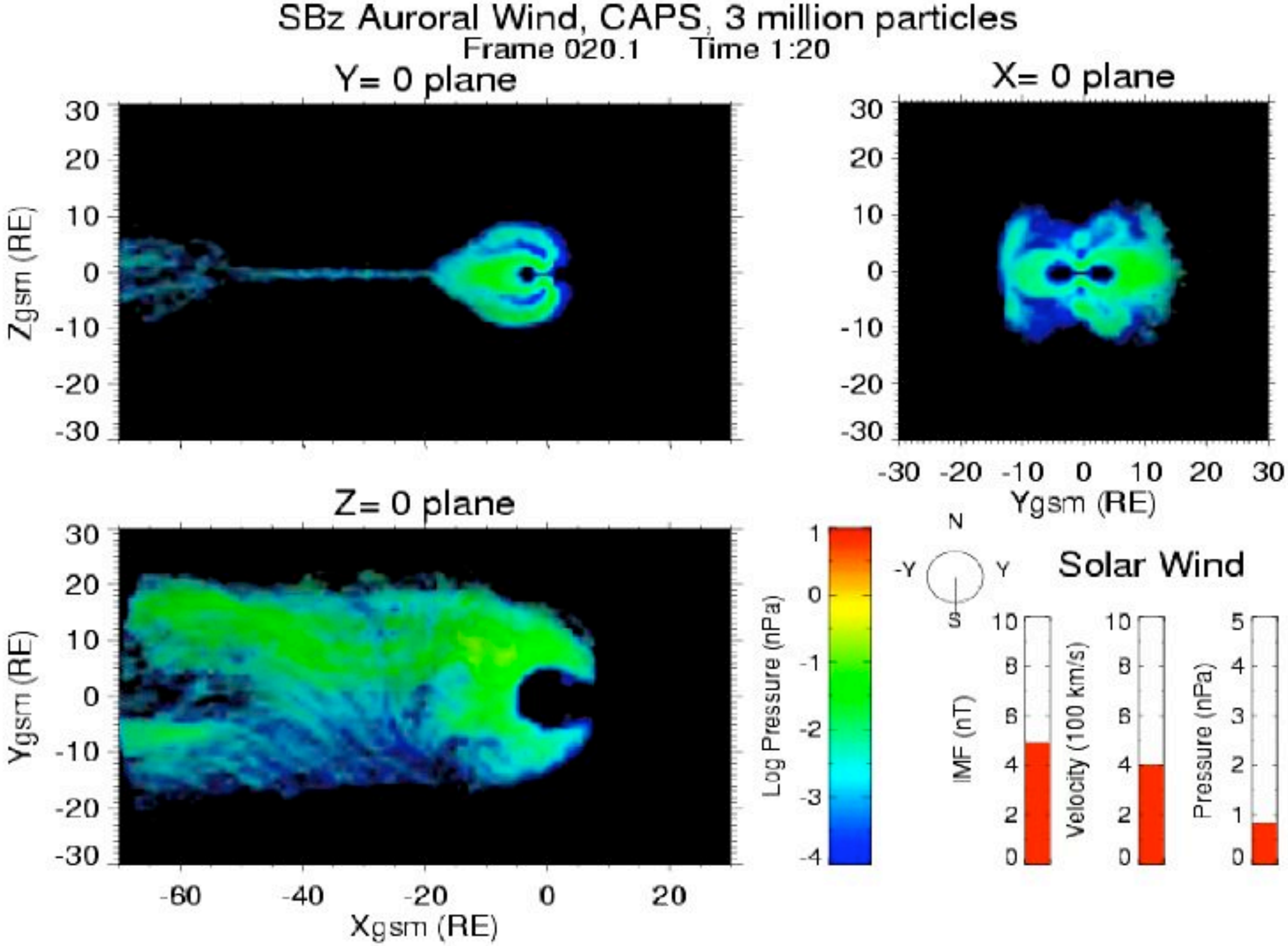
Solar Wind Pathways to Plasmasheet



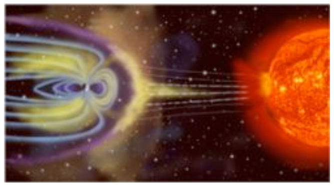


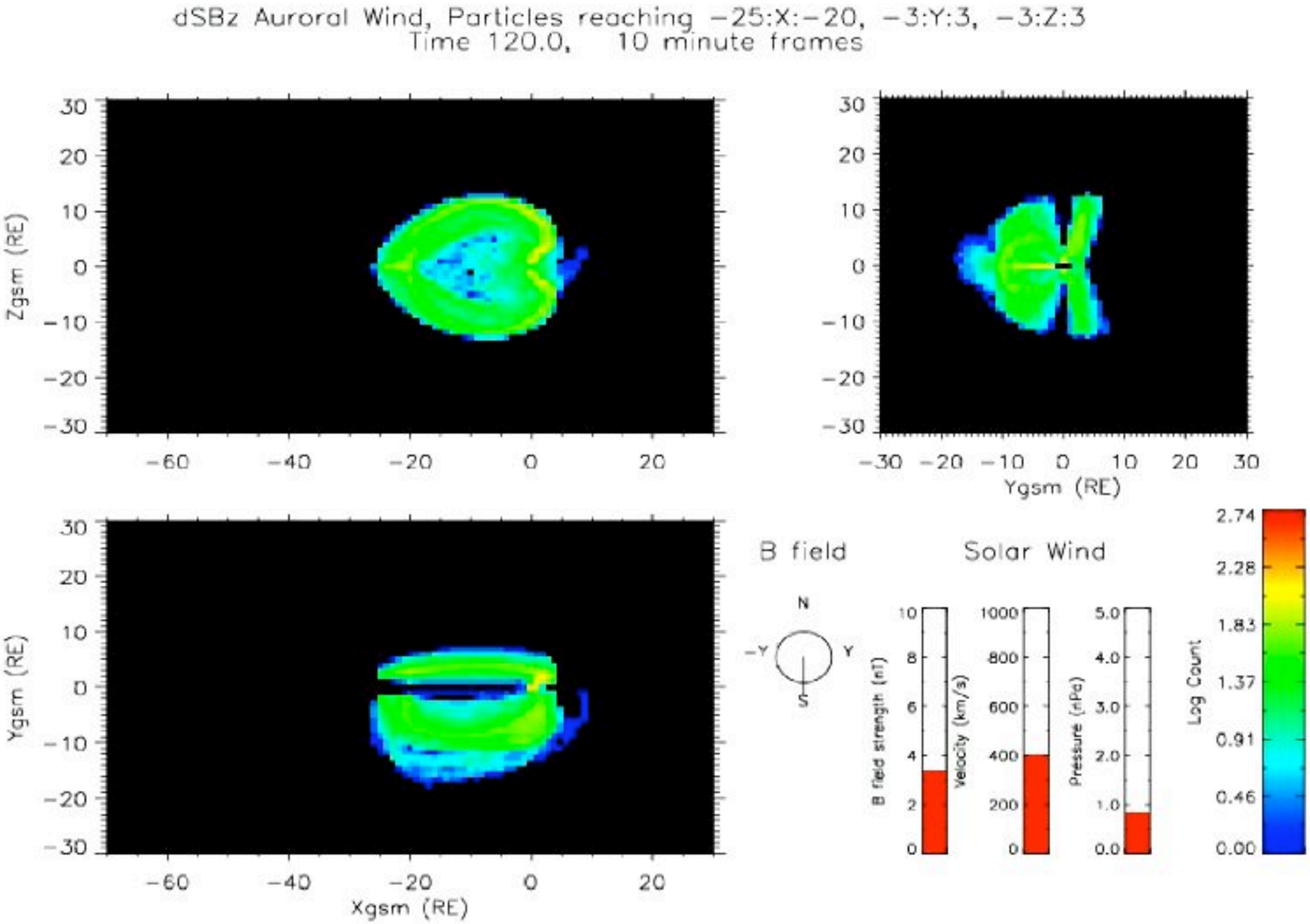
Auroral Wind Circulation: N/SBz



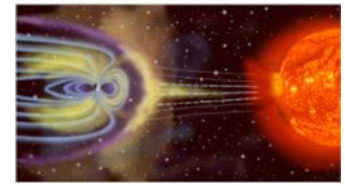


Auroral Wind Pathways to Plasmasheet

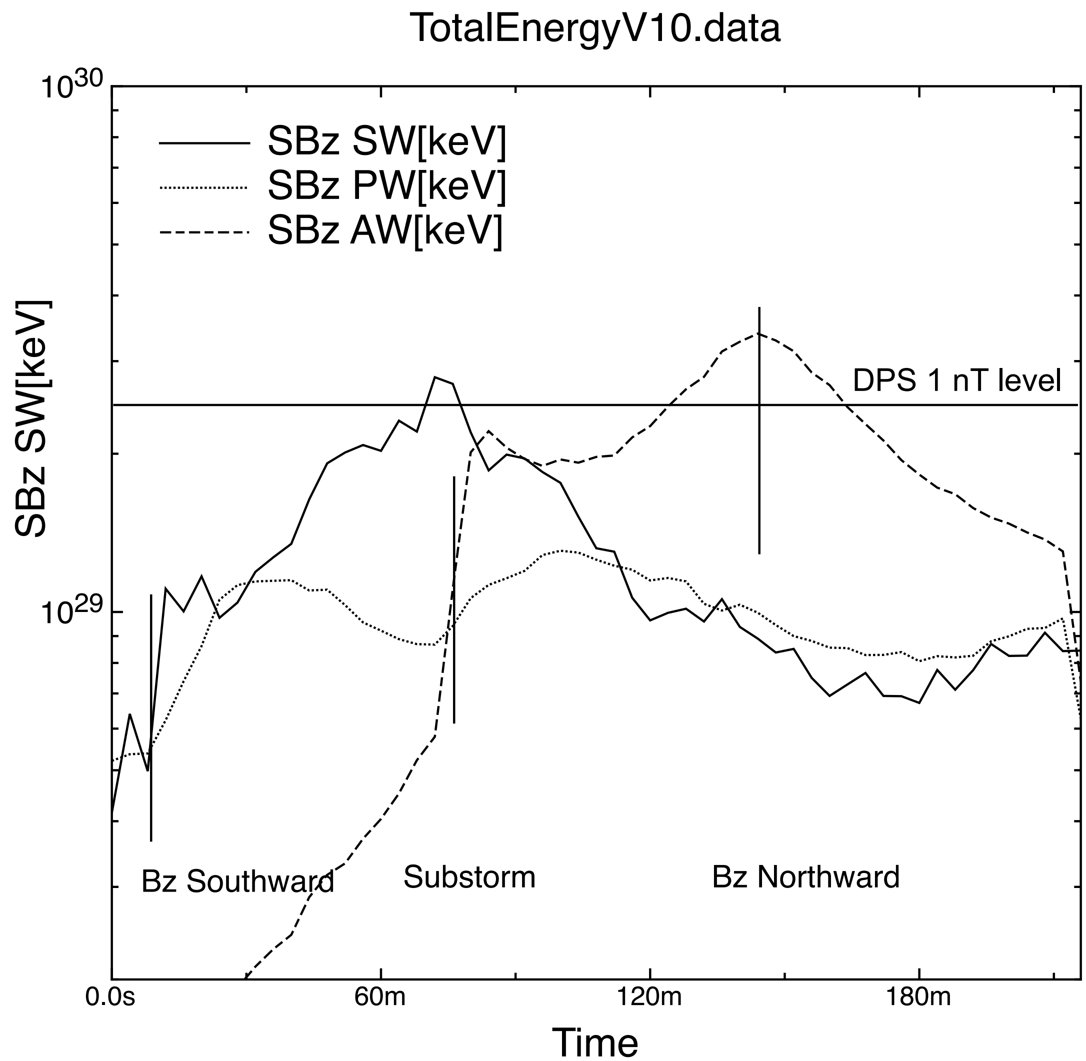




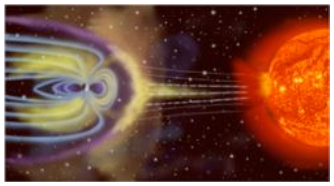
Global Energy Content - SBz

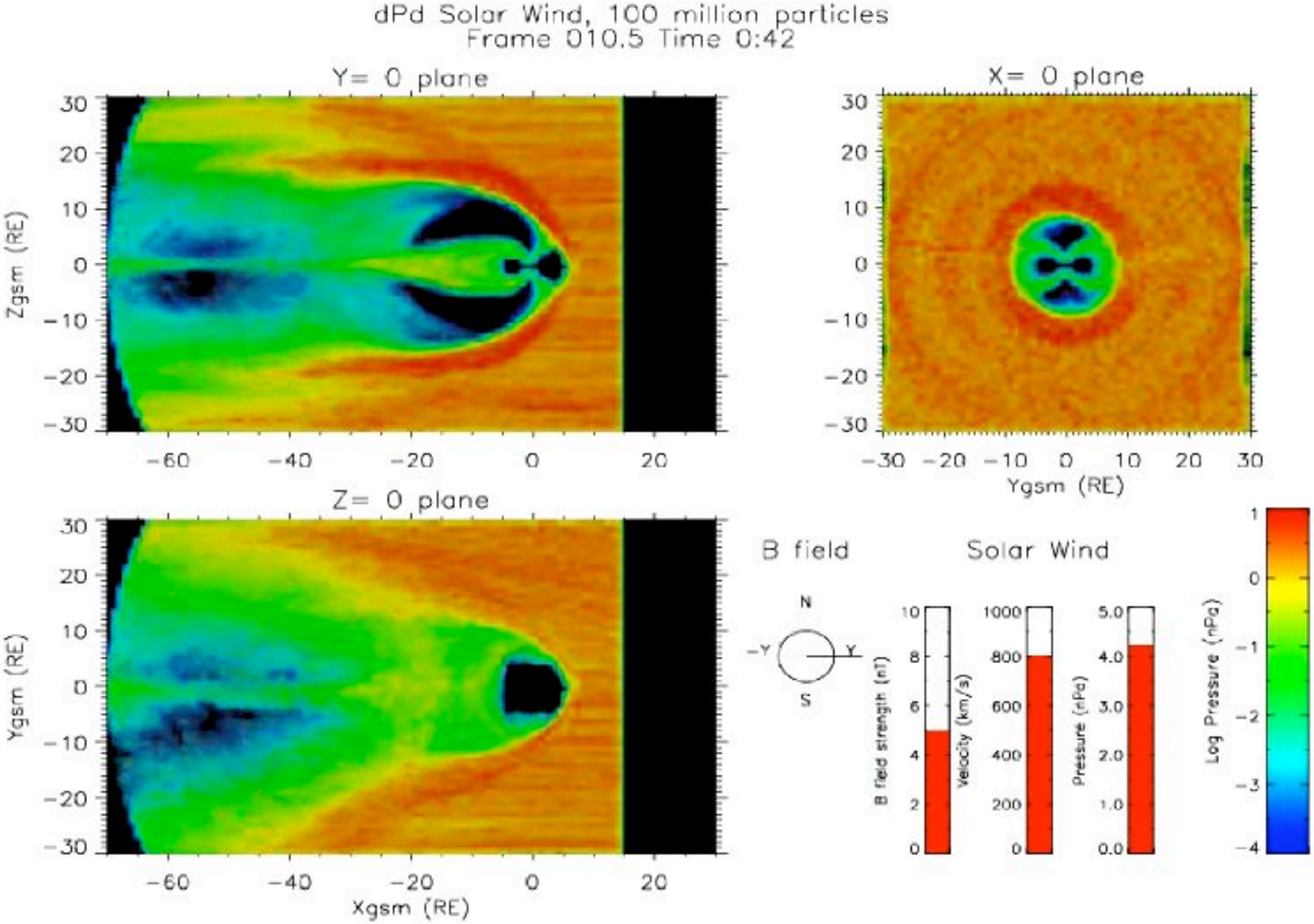


- Low total energy content from MHD results
- Comparable polar wind and solar wind initially
- Switch from solar wind to auroral wind with substorm onset (tail reconnection)
- Auroral wind takes over in SS

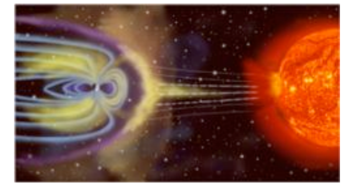


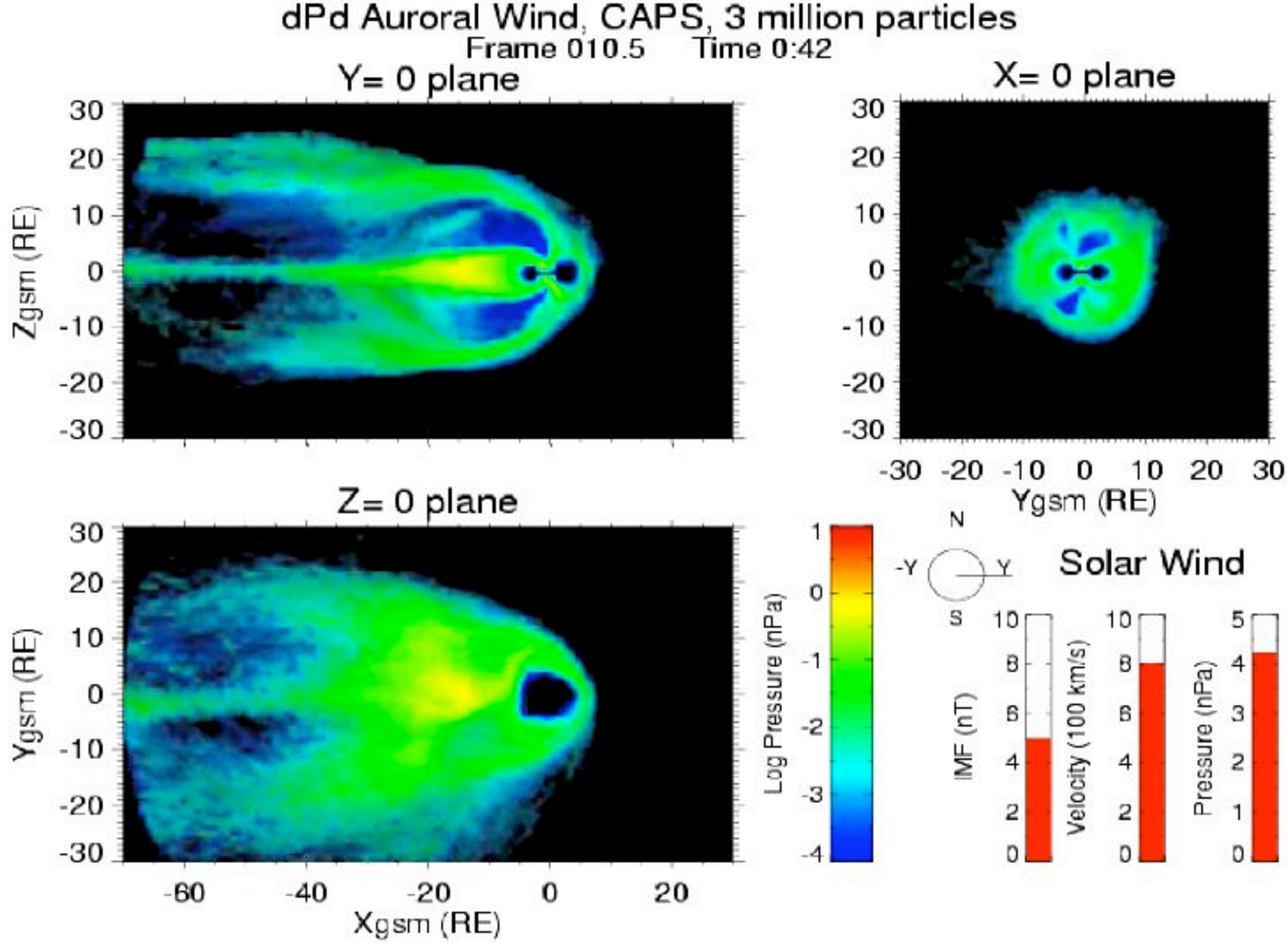
Solar Wind for ∇Pd



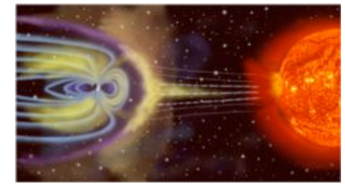


Auroral Wind Circulation: ∇Pd

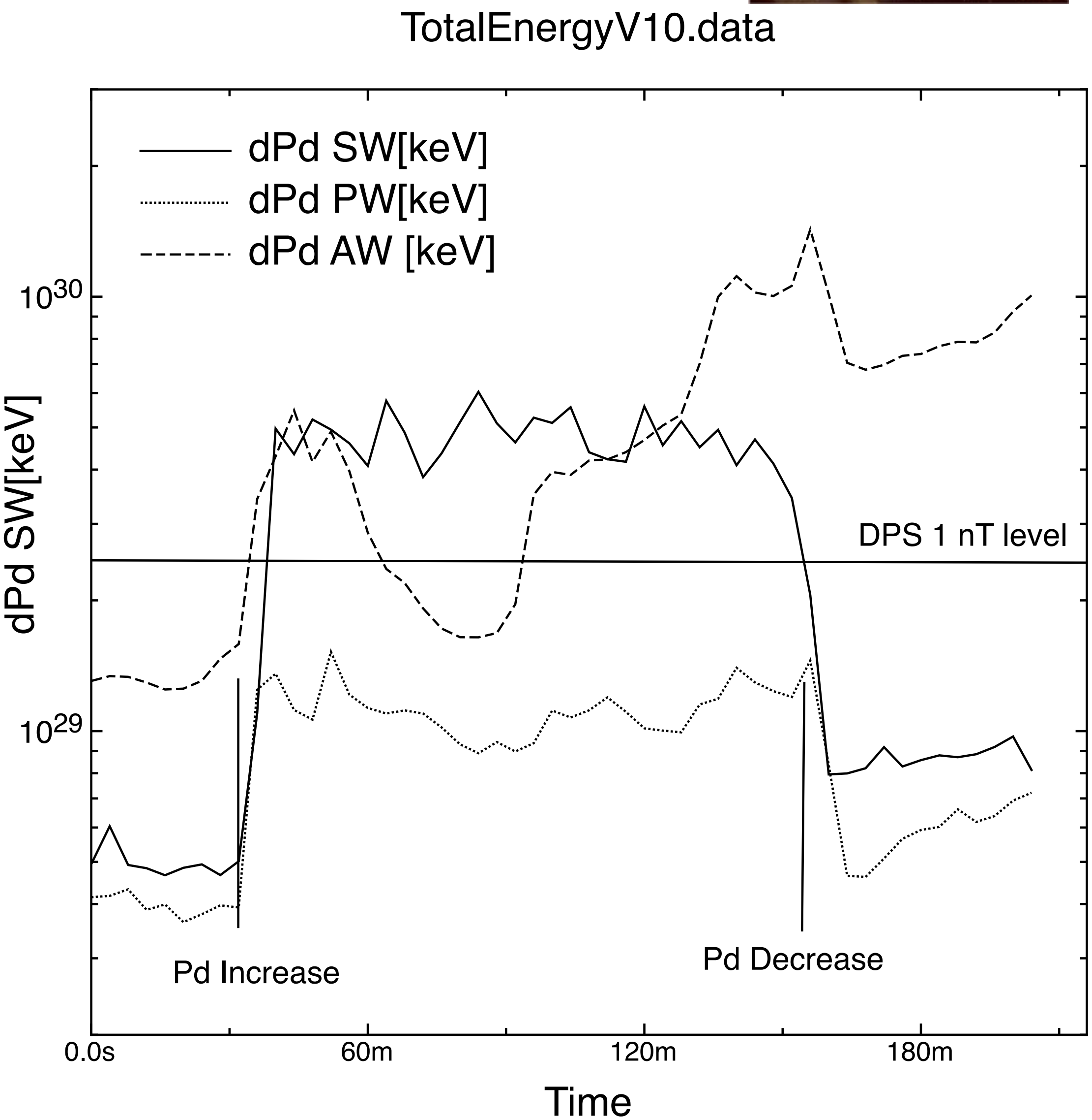




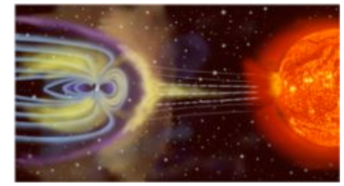
Global Energy Content - ∇Pd



- Again, low total energy content from MHD results
- Comparable polar wind and solar wind initially, AW starts higher than either
- SW responds to Pd
- AW responds initially, fades, then more when outflows arrive
- AW remains late



CONCLUSIONS



- Ionospheric outflows always important but O^+ increases steeply with solar wind drivers, especially with Pd, and Dst
- New empirical models permit detailed local response to global magnetospheric inputs.
- Imposing global circulation model (GCM) inner boundary conditions yields outflows consistent with statistical databases
- These outflows acquire substantial hot plasma energy content in GCM fields.

Future Work

- Improve empirical or simulation models of wave environments important for electron precipitation and ion heating
- Incorporate topside ionospheric outflow physics in global simulations
- Study realistic storm sequences